

Pratt & Whitney – FAA CLEEN III Consortium

Industry Day / Public Session

May 3rd 2023



GO BEYOND

CLEEN III: Fan Module Technologies Development &
TALON® X+ Combustor Module Enhancements
693KA9-21-T-00005

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Pratt & Whitney - World Leader



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Pratt & Whitney is a world leader in the design, manufacture and service of aircraft engines and auxiliary power systems, and has been revolutionizing modern flight and going beyond for nearly 100 years.

POWERING SUSTAINABLE AVIATION™

SMARTER.
CLEANER.
GREENER.

SINCE 2006, PRATT & WHITNEY HAS
TRIPLED PRODUCTION WHILE ...

REDUCING TOTAL GREEN- HOUSE GAS EMISSIONS EQUIVALENT TO	627,000 PASSENGER VEHICLES DRIVEN FOR ONE YEAR
REDUCING TOTAL WATER USAGE EQUIVALENT TO	596,000 INDIVIDUALS' WATER NEEDS MET FOR ONE YEAR
INCREASING TOTAL WASTE RECYCLING RATE BY	+ 19% WASTE RECYCLING

2050 Commitment to NET Zero Emissions

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P&W COMMERCIAL FLEETS

LEGACY ENGINES

WITH MORE THAN 13,000 LARGE COMMERCIAL ENGINES INSTALLED TODAY, PRATT & WHITNEY PROVIDES DEPENDABLE POWER TO HUNDREDS OF AIRLINES AND OPERATORS EVERY DAY.



Photo: Boeing
BOEING 757



Photo: Airbus
AIRBUS A320

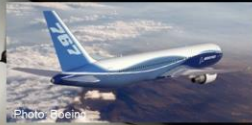


Photo: Boeing
BOEING 767



Photo: Airbus
AIRBUS A330



Photo: Boeing
BOEING 777



Photo: Airbus
AIRBUS A350



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PRATT & WHITNEY GTF

THE PRATT & WHITNEY GTF™ ENGINE IS THE ONLY GEARED PROPULSION SYSTEM DELIVERING INDUSTRY-LEADING SUSTAINABILITY BENEFITS AND DEPENDABLE, WORLD-CLASS OPERATING COSTS.

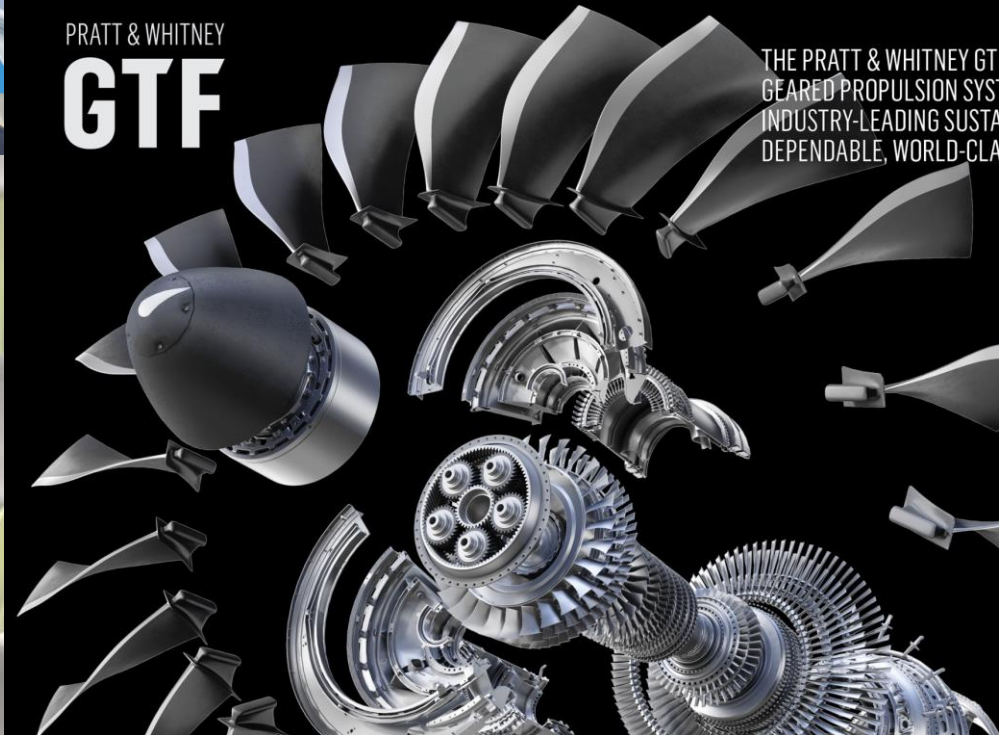


Photo: Airbus
AIRBUS A320neo



Photo: Airbus
AIRBUS A220



EMBRAER 190/195-E2

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P&W Future Strategic Growth



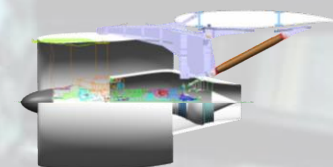
Current Engines



Geared Architecture
Higher BPR / OPR,
Component Efficiencies

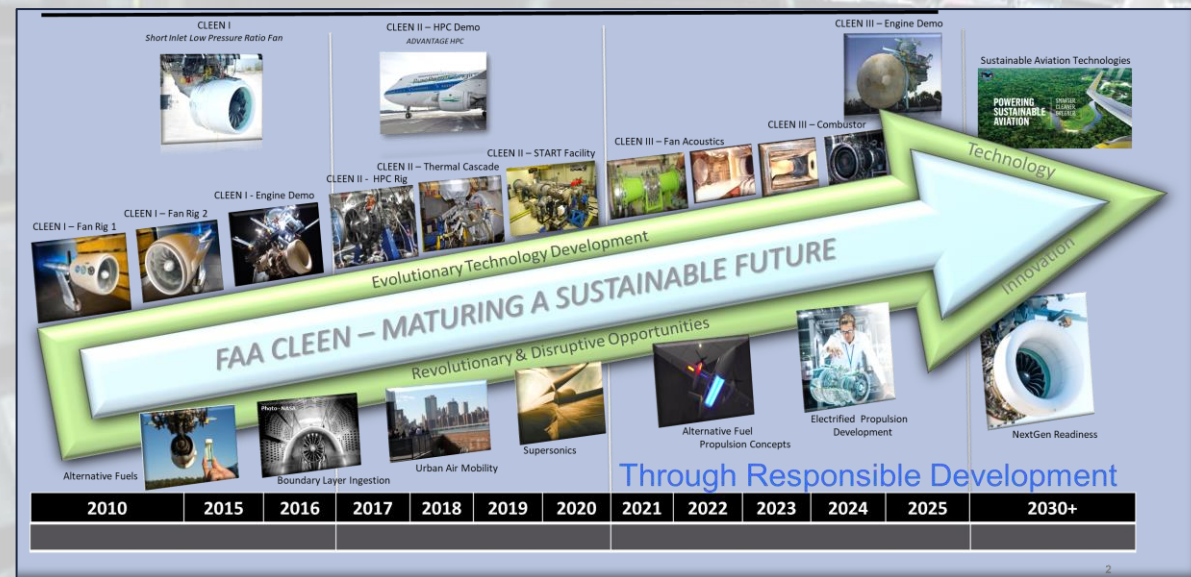


Thermal &
Propulsive
Efficiency



GTF-Gen2

UHB Propulsion System
Next Generation Core,
Light weight materials,
Sustainable Advantages



INNOVATION & TECHNOLOGY

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CLEEN Drives Contributions To Aviation



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CLEEN I

Propulsive Efficiency



Low Pressure Ratio Fan – Short Inlet Development

Novel Architecture Potential

Propulsion Metric Benefits

**1.5% Fuel
Burn Reduction**

**~30,000 gallons of fuel
potential per year / plane**

*A320 Neo, 2.0 hr flights, 3100 annual flight hours

CLEEN II

Thermally Efficiency



High Compressor Aero
Efficiency Airfoils

High Pressure Turbine
Aero/Thermal Efficiency
PSU START Facility

Engine / Airframe Level



**1.4% Fuel
Burn Reduction**

Fleet Level

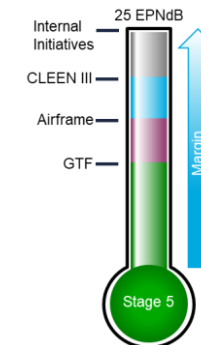


**29,000 gallons of fuel
saved per year per plane***

*A320NEO, 2.0 hour flights, 3,100 annual flight hours

CLEEN III

Sustainability



Strive to be the best
aerospace engine company
FOR the world

FOR OUR PRODUCTS

Emissions

Reduce the environmental impacts of our products
Work with our customers to reduce in-service impacts

Sustainable Products
Design, manufacture and service products to minimize impacts
Use Ecodesign to drive product innovation



FOR OUR SITES

Zero Waste

All by-products 100% recycled
Increase efficiency and reduce "non-product" output

Carbon Neutral
Use only sustainable energy sources
Lower our footprint to avoid future impacts and costs



FOR OUR PEOPLE

Influence

Be a force for positive change
Support and engage employees and communities in building a better future



Owning Our Future

**Fuel Burn
0.8 %**

**NOx / nVPM
5% / 10%**

**EPNdB (stg 5)
3**

2010

2017

2015

2020

2021

2026

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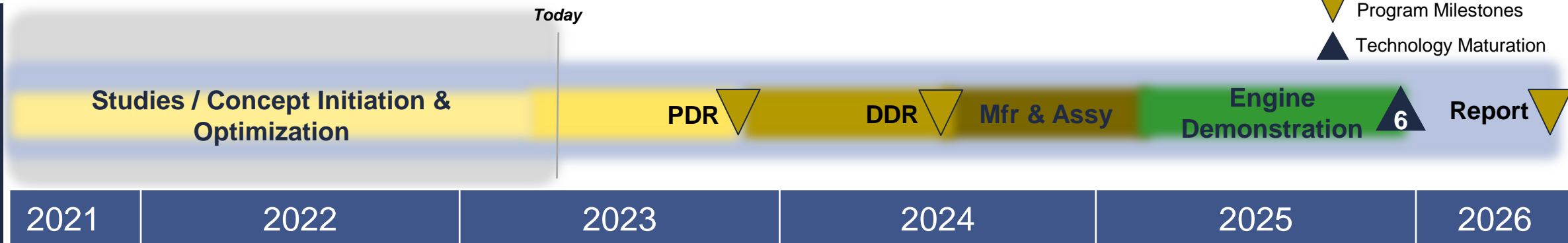
Pratt & Whitney's CLEEN III Technologies



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- ▼ Program Milestones
- ▲ Technology Maturation

Program
Technology Development

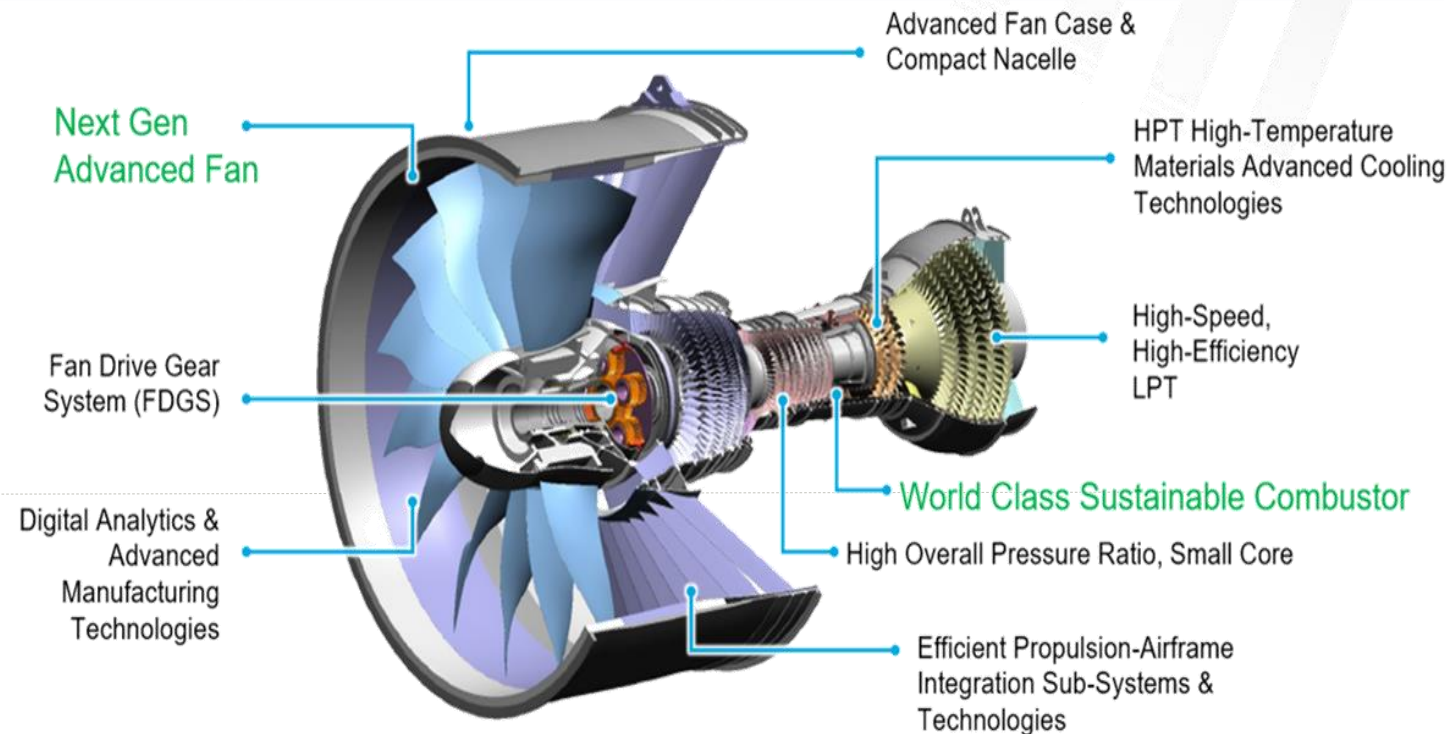


Fan Technologies

Additively Manufactured Acoustic Liners
Low-Loss Intra-Stage Liners
Low-Count / Low-Noise Guide Vanes

Combustor Technologies

Noise Robust Swirler
Low Pattern Factor Combustor
Floatwall+



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Fan Module - Accomplishments

Today

Studies / Concept Initiation & Optimization

PDR

DDR

Mfr & Assy

Engine Demonstration

6

Report

2021

2022

2023

2024

2025

2026

- Additively Manufactured Acoustic Liners
- Low-Loss Intra-Stage Liners
- Low-Count / Low-Noise Guide Vanes

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- Wind Tunnel Testing

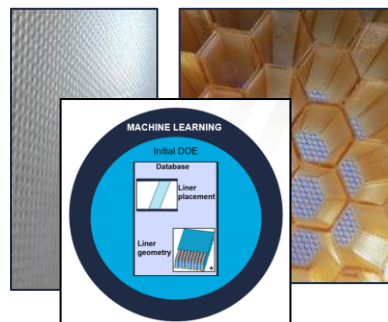
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Additively Manufactured (AM) Acoustic Liners

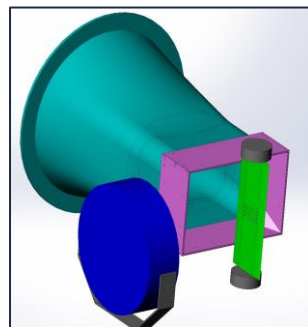
- ✓ Attained polymer AM fabrication knowledge for challenging acoustic part treatment
- ✓ Polymer AM materials have been down-selected and their manufacturing processes identified
- ✓ Polymer AM flat panels have been drag and impedance tested

Low-Loss Intra-Stage Liners & Low-Count / Low-Noise Guide Vanes

- ✓ Compact liner impedance testing has progressed with a new configuration currently under evaluation.
- ✓ Conceptual hardware design trades have been evaluated
- ✓ Demonstrator engine designs have been formulated
- ✓ Machine Learning framework has been established and is being utilized
- ✓ New aero performance architectures that will compliment acoustic treatment objectives have been identified



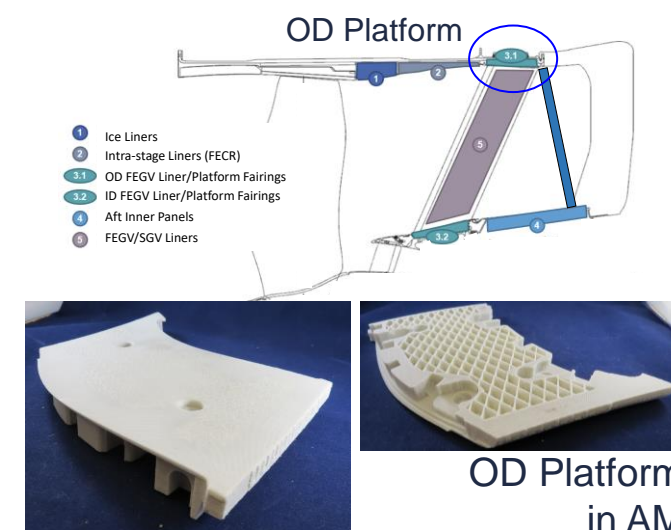
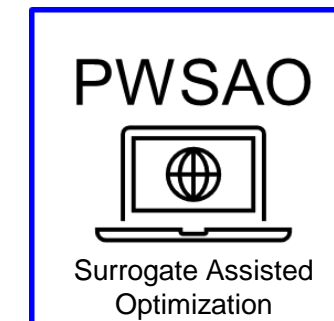
Advanced MFG & Machine Learning



Acoustic Tunnel & Grazing Flow

Fan Module – Next 6-Months

- Execute the system demonstration engine preliminary design
- Continue validation of Machine Learning w/ integration of favorable noise reduction predictions
- Develop new aero performance architectures complimenting acoustic treatment objectives
- Continue wind tunnel drag and impedance testing with the curved acoustic treatment panel on the guide vanes
- Advance manufacturing readiness of the curved polymer AM panels
- Place orders for long-lead material and hardware purchases



Combustor Module - Accomplishments

Today

Studies / Concept Initiation & Optimization

PDR

DDR

Mfr & Assy

Engine Demonstration

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- Noise Robust Swirler
- Low Pattern Factor Combustor
- Floatwall+

4

Noise Robust Swirler (NRS)

- ✓ Selected NRS concepts for SNR round 2 testing
- ✓ Preliminary downselect of demo swirler configuration

- Full Annular Rig Testing

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Low Pattern Factor (LPF)

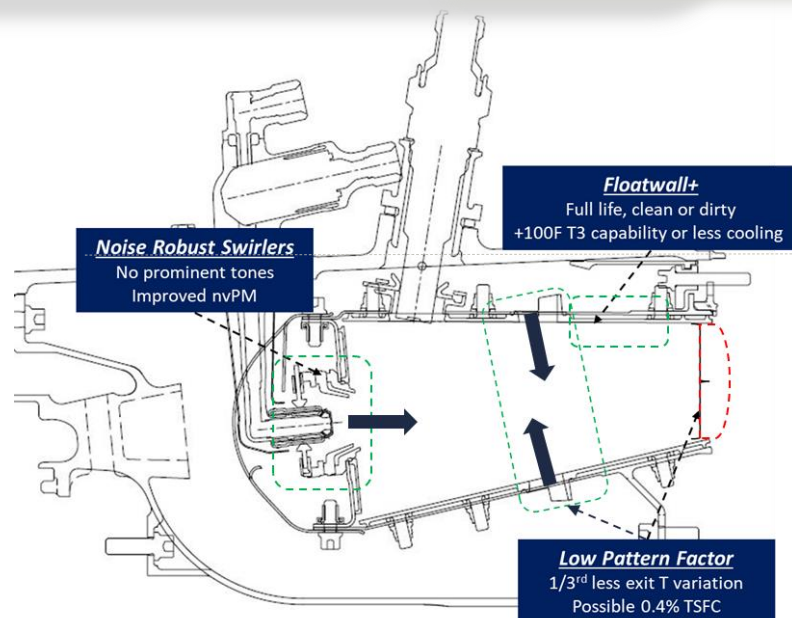
- ✓ Build 2 Pattern Factor Visualization Rig (PFVR) test completed; confirms improvements for quench hole configuration
- ✓ Preliminary downselect of demo quench configuration

Floatwall+ (FW+)

- ✓ Selected rainbow wheel panel configurations for Multi-Sector Full Annular Rig (MS FAR)
- ✓ Preliminary downselect of demo panel configuration

Full Annular Rig / Demo Combustor

- ✓ Kicked off preliminary design for demo combustor configuration



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Combustor Module – Next 6-Months

- Noise Robust Swirler (NRS) - Start round 2 SNR testing of NRS concepts to measure tones
- Low Pattern Factor (LPF) - Start Low Cost FAR (LC FAR) combustor test to demonstrate reduced pattern factor
- Floatwall+ (FW+) - Start MS FAR combustor test to measure improved metal temperatures
- Full Annular Rig / Demo Combustor
 - Finalize Integrated Full Annular Rig (FAR) Build 1 combustor configuration
 - Kick off detailed design for demo combustor configuration



Single Sector



Multi-Sector and Full Annular

Thank You.



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